Physics 228– Exam II
March 25, 2007
Profs. Coleman and Zimmermann

Your name sticker ⇒ with exam code

SIGNATURE: _____

1. **Turn off your cell phone now!**
2. The exam will last from 3:00 p.m. to 4:20 p.m. Use a #2 pencil to make entries on the answer sheet. Enter the following ID information now, before the exam starts.
3. In the section labelled NAME (Last, First, M.I.) enter your last name, then fill in the empty circle for a blank, then enter your first name, another blank, and finally your middle initial.
4. Under STUDENT # enter your 9-digit Identification Number.
5. Enter 228 under COURSE, and your section number (see label above) under SEC.
6. Under CODE enter the exam code given above.
7. During the exam, you may use pencils, a calculator, and one **handwritten** 8.5 x 11 inch sheet with formulas and notes, without attachments.
8. There are 16 multiple-choice questions on the exam. For each question, mark only one answer on the answer sheet. There is no deduction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess. At the end of the exam, **hand in the answer sheet and the cover page**. Retain this question paper for future reference and study.
9. When you are asked to open the exam, make sure that your copy contains all 16 questions. Raise your hand if this is not the case, and a proctor will help you. Also raise your hand during the exam if you have a question.
10. Please **SIGN the cover sheet under your name sticker.** A proctor will check your name sticker and your student ID sometime during the exam. Please have them ready.
11. Good luck.

Possibly Useful Information

speed of light: $c = 3.00 \times 10^8$ m/s

Ångström: 1 Å $= 10^{-10}$ m

electron charge: $q_e = -e = -1.602 \times 10^{-19}$ Coulombs

electron mass: $m_e = 9.11 \times 10^{-31}$ kg

1 eV $= 1.602 \times 10^{-19}$ J

$\hbar = 1.0545 \times 10^{-34}$Js

$h = 6.626 \times 10^{-34}$Js

WITH SOLUTIONS

1. A 30-year-old woman takes a trip on a rocket, leaving her 20-year-old brother behind at rest on the Earth. She travels at a speed of 0.8 c, and is gone for 20 years according to her younger brother's clock. When she returns, how many years older or younger is she than her brother? [Hint. Be careful. Both of them age.]

a) 2 years younger
b) 2 years older
c) 4 years older
d) 10 years older
e) 8 years older

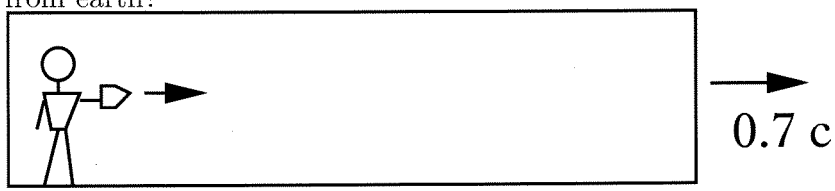
$2t = 20\,yrs \Rightarrow t = 10\,yrs$

$t = \gamma T \quad \gamma = \frac{1}{\sqrt{1-(0.8)^2}} = (0.6)^{-1}$

$\Rightarrow T = t/\gamma = 6\,yrs$

$t_B = 30 + 2T = 42\,yrs \quad t_B = 40\,yrs.$

2. A spaceship is moving at speed 0.70c to the right relative to earth. Standing at the rear of the ship, a woman fires a space gun, and the bullet goes forward inside the ship at a speed of 0.90c relative to the spaceship. What is the bullet's speed as measured from earth?



a) 0.20c
b) 1.60c
c) 0.92c
d) 0.98c
e) 0.54c

$v' = \frac{u+v}{1+(uv/c^2)} = \frac{0.7+0.9}{1+(0.7)(0.9)}\,c$

$= 0.981\,c$

3. The rest mass of a particle is m. In order for its *total* energy to be twice its rest energy, its momentum must be:

a) $mc/2$
b) $mc/\sqrt{2}$
c) mc
d) $\sqrt{3}mc$
e) $2mc$

$E = m_0c^2\gamma = 2m_0c^2$

$\Rightarrow \gamma = 2 \Rightarrow \gamma^2 = 4 \Rightarrow u = \frac{\sqrt{3}}{2}c$

$p = m_0u\gamma = m_0c\,\frac{\sqrt{3}}{2} \times 2 = \sqrt{3}\,m_0c$

Alternatively $E^2 - p^2c^2 = (mc^2)^2 \Rightarrow (pc)^2 = 4(mc^2)^2 - (mc^2)^2 = 3(mc^2)^2 \Rightarrow p = \sqrt{3}\,m_0c$

4. Which of the following statements about the photoelectric effect is false?

a) The stopping potential increases linearly with the frequency of the incident light
b) The stopping potential is independent of the intensity of the incident light
c) The threshold frequency is independent of the intensity of the incident light
d) The work function of the metal is independent of the frequency of the incident light
e) The maximum kinetic energy of the photoelectrons increases linearly with the intensity of the incident light

5. The temperature of a black body increases from 300K to 1000K. Which of the following statements about the spectrum of emitted EM radiation is false?

a) The peak shifts to higher frequency.
b) The integrated intensity increases.
c) The intensity at long wavelengths decreases.
d) The intensity at short wavelengths increases.
e) The shape of the spectrum is still described by the Planck law.

6. The threshold wavelength for the photoelectric effect in silver is 262 nm, i.e. this is the longest wavelength which will just barely cause electrons to be emitted from the surface. For what wavelength will the photoelectric stopping potential be 1.36 V?

a) 204 nm
b) 175 nm
c) 368 nm
d) 912 nm
e) 127 nm

$\frac{hc}{\lambda_0} = \phi \qquad \frac{hc}{\lambda} = E + \phi = E + \frac{hc}{\lambda_0}$

$\Rightarrow \frac{1}{\lambda} = \left(\frac{E}{hc} + \frac{1}{\lambda_0}\right)$

$\lambda = \left(\frac{E}{hc} + \frac{1}{\lambda_0}\right)^{-1} = \left[\left(\frac{1.36 \times 1.6 \times 10^{-19}}{6.62 \times 10^{-34} \times 3 \times 10^8}\right) + \frac{1}{262 \times 10^{-9}}\right]^{-1}$

$= 204 \times 10^{-9}\,m = 204\,nm$

7. An electron has a DeBroglie wavelength of 0.13 nm. What is its kinetic energy?

a) 9.5×10^3 eV
b) 89 eV
c) 9.3×10^{-3} eV
d) 1.3 eV
e) 314 eV

$E = \frac{1}{2m}p^2 = \frac{1}{2m}\left(\frac{h}{\lambda}\right)^2$

$E = \frac{1}{2\times(9.1\times10^{-31})} \times \left(\frac{6.62\times10^{-34}}{0.13\times10^{-9}}\right)^2$

$= 1.42\times10^{-17}\,J \simeq 89\ eV$

8. A helium-neon laser is emitting 10^{17} photons every second, all at a wavelength of 633 nm. What is the laser's power output?

a) About 0.75 W
b) About 0.03 W
c) About 12 W
d) About 0.20 W
e) About 4.1 W

$P = nhf = n\frac{hc}{\lambda}$

$= 10^{17} \times \frac{(6.63\times10^{-34}\times3\times10^{8})}{633\times10^{-9}} = 0.03W$

9. Which of the following statements are true?

- I: A proton confined within a nucleus cannot be perfectly at rest.
- II. A particle of finite lifetime cannot have a precisely defined mass.
- III. The position and momentum of a particle cannot be simultaneously measured to arbitrary accuracy.

a) I and III are true; II is false
b) All three statements are true
c) All three statements are false
d) III is true; I and II are false
e) II and III are true; I is false

10. The wavelength of photon A is twice that of photon B. What is the ratio of the speed of photon A to that of photon B?

a) 1/4
b) 1/2
c) 4
d) 2
e) 1

11. A photon and an electron have the same wavelength.

a) either may have the greater momentum, depending on the wavelength.
b) the photon has the greater momentum.
c) the electron has the greater momentum.
d) they have the same momentum.
e) only electrons carry momentum.

12. A particle in a one-dimensional box (with $V = 0$ between infinitely high side walls) has a ground-state energy of 2 eV. In the first two excited states, the particle's energy would be respectively

a) 8 eV and 18 eV
b) None of the other answers
c) 4 eV and 8 eV
d) 3 eV and 4 eV
e) 4 eV and 6 eV

$E = \frac{1}{2m}\left(\frac{h}{2L}\right)^2 n^2 = 2eV \times n^2$

$\{E_2, E_3\} = \{2eV\times2^2,\ 2eV\times3^2\}$

$= \{8eV,\ 18eV\}$

13. The statements below all agree with the Bohr model for the hydrogen atom. One of them disagrees with the Schrödinger model for the hydrogen atom. Which is it?

a) In the hydrogen atom, the relationship between total energy, E, potential energy, U, and kinetic energy, K, is given by $E = K + U$.

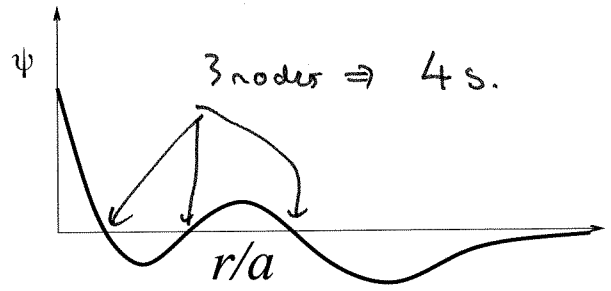
b) The frequency, f, of a photon emitted when an electron makes a transition from the i^{th} orbit to the j^{th} orbit is given by $hf = E_i - E_j$.

c) The orbital angular momentum of the lowest possible energy level, i.e. the ground state, is $L = 1\hbar$.

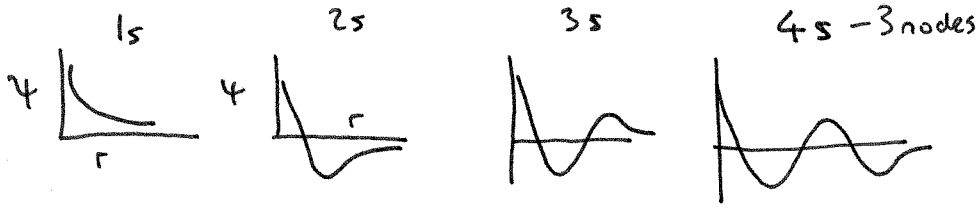
d) The potential energy function for the atom is given by $v(r) = -k_e e^2/r$

e) The energy for the ground state of hydrogen is –13.6 eV.

14. The wavefunction $\psi(r)$ of an electron in a hydrogen atom with $l = 0$ is shown in the figure, where r is the distance from the nucleus, and a is a constant. What is the principal quantum number (n) for this state?



a) 4
b) 3
c) 2
d) 1
e) 5

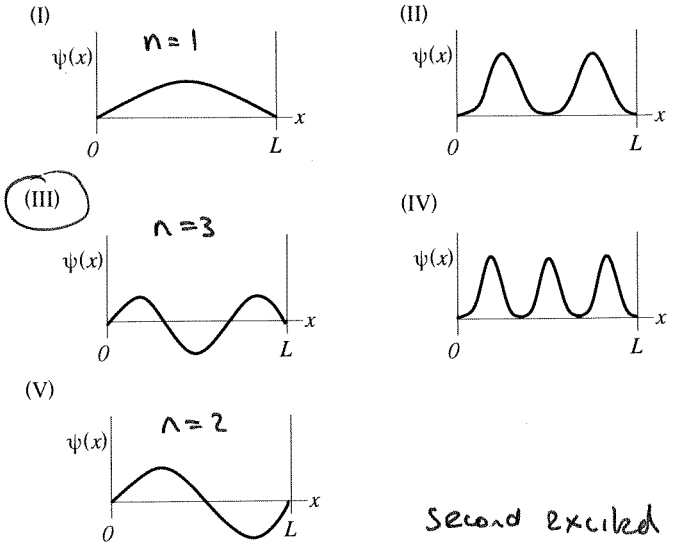


15. An electron in an f-state of the Hydrogen atom has a magnetic quantum number $m_z = +3$. What is its component of angular momentum along the z-axis?

a) $-3\hbar$
b) $\sqrt{12}\hbar$
c) $\sqrt{6}\hbar$
d) $\sqrt{2}\hbar$
e) $3\hbar$

$L_z = \hbar m_z = 3\hbar$

16. A particle in a box of length L is in its second *excited* state. Which diagram in the figure best describes its wavefunction?



a) I
b) II
c) III
d) IV
e) V

second excited state ⇒ n = 3